NOAA Teacher at Sea Lesson Plan
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TAS 2010

Activity Title: Salinity and Temperature Patterns in the Arctic Ocean

Subject (Focus/Topic): Earth Science – Physical Oceanography

Grade Level: 9th – 12th Grade

Average Learning Time: 1 class period (65 minutes)

Lesson Summary (Overview/Purpose)
Students will prepare maps showing surface salinity and temperature patterns in the Arctic Ocean and evaluate patterns to determine causes of variations relative to sea ice distribution and in comparison with global patterns.

Overall Concept (Big Idea/Essential Question)
This activity will introduce students to global patterns of surface salinity and temperature in the world's oceans and the factors that cause variations from average values. Students will consider how unique characteristics of the Arctic Ocean result in differences from global patterns.

Specific Concepts (Key Concepts)
- The average surface salinity of the world's oceans is 35 o/oo.
- Factors such as surface water runoff, evaporation and precipitation, and the formation and melting of sea ice cause local variations in salinity.
- Surface temperature patterns in the world's oceans are controlled primarily by latitude.
- Average surface salinities in the Arctic Ocean are lower than worldwide average salinity, influenced by the formation and melting of Arctic sea ice.
- Surface salinity and temperatures patterns in the Arctic Ocean can be used to estimate the location of sea ice.

Focus Questions (Specific Questions)
- What factors influence the salinity and temperature of surface water in the world's oceans?
- Which of the following cause an increase in surface salinity and which cause a decrease in salinity: runoff from rivers; high evaporation rates; precipitation; formation of sea ice; melting of sea ice?
- How does latitude influence surface seawater temperature?
- What is the freezing point of seawater?
- How and why do surface salinity and temperature patterns in the Arctic Ocean differ from global patterns?

Objectives/Learning Goals
- Given maps that show surface salinity and temperature data from select locations in the Arctic Ocean, students will prepare color-coded maps to show patterns of surface salinity and temperature.

- Students will interpret the salinity patterns in the Arctic Ocean based on comparison with global patterns and identify two or three reasons that the patterns in the Arctic differ from global patterns.
- Students will analyze temperature patterns and infer the approximate location of sea ice during the time when the data were collected.
- Students will identify three sources of water that account for the patterns of salinity and temperature identified in the Arctic.
- Students will make inferences about how salinity and temperature patterns in the Arctic Ocean may vary according to the season.

Background Information

Salinity is a measure of the amount of dissolved solids in seawater. Worldwide average salinity of surface seawater is approximately 35 parts per thousand ($^{o}/_{oo}$) or practical salinity units (PSU). Sources of dissolved salts in seawater include elements dissolved from continental sediment and rocks transported to oceans by rivers and groundwater, and gases from volcanoes on land and on the sea floor.

Variations in surface salinity result from climate variations that influence evaporation and precipitation rates, runoff from rivers along continental coastlines, and the formation and melting of ice at high latitudes. Maps of global surface seawater salinities typically show values lower than average near coastlines where major rivers discharge freshwater to the ocean, near polar latitudes where glacial melt water enters oceans, and near the tropics where precipitation dilutes the salinity of surface waters. Salinity values are greatest near high-= pressure belts at subtropical latitudes where there is generally high evaporation and low precipitation. Regions of highest values tend to be in the center of major ocean gyres such as the Sargasso Sea region in the North Atlantic gyre and near the middle of the North and South Pacific gyres.

The major factor that influences surface seawater temperatures is intensity and amount of incoming solar radiation (insolation) received throughout the year. This factor is controlled primarily by latitude. Surface currents also influence surface temperature patterns, with warm currents dominating the western boundaries of ocean gyres and cold currents dominating the eastern boundaries.

Background information about patterns of salinity and temperature is provided in the oceanography chapters of an Earth Science textbook or general oceanography textbook and should be assigned as background reading prior to this lesson. If no textbook is available, background information about ocean water characteristics is available on many websites, including the following sites.

- http://marinebio.org/oceans/ - from the MarineBio Conservation Society. This site provides good summary background information about oceans, including sections about ocean chemistry and the ocean and temperature.
- http://science.nasa.gov/earth-science/oceanography/ - from NASA. A great site with information about how NASA satellites are used to measure characteristics of "The Physical Ocean."
- http://www.windows2universe.org/earth/Water/ocean.html&edu=high – Windows to the Universe is from the National Earth Science Teachers Association. The Oceans section provides detailed background information about the characteristics of ocean water, comparable to the information found in an oceanography or earth science textbook, with excellent graphics.

- http://oceanexplorer.noaa.gov/welcome.html – from NOAA, the Education section of this site provide searchable lesson plans about all aspects of oceanography that can be used as background lessons.

Maps of global seawater salinity and temperature are available at numerous websites, including those listed below.

- Two links to general maps of sea surface salinity:
  http://science.nasa.gov/earth-science/oceanography/physical-ocean/salinity/
  http://aquarius.gsfc.nasa.gov/overview-sss.html
- http://aquarius.gsfc.nasa.gov/education.html – NASA Jet Propulsion Laboratory. This site describes a new mission to measure and map sea surface salinity from space.
- http://neo.sci.gsfc.nasa.gov/Search.html – from NASA Earth Observations. The Oceans tab on this site provides access to images of maps of Sea Surface Temperatures from the 1980s through the present.
- http://earthobservatory.nasa.gov/GlobalMaps/view.php?d1=MYD28M – from NASA Earth Observatory. This site provides a time series animation of maps of Sea Surface Temperatures from July 2002 through February 2011. Students can watch how temperature patterns change seasonally and compare patterns at different latitudes.

An introductory lesson about the characteristics of seawater can precede this lesson or this lesson can be used to introduce the topic.

Common Misconceptions/Preconceptions

- The Arctic Ocean is inaccessible to modern research vessels.
- Seawater does not freeze because of the dissolved salts. – OR –
- The Arctic Ocean is always frozen.
- Sea ice comes from continental glaciers that break off at the coastline and become icebergs.
- The Arctic Ocean is saltier (OR less salty) than average because of the presence of sea ice.

Materials:

Lesson Handout entitled "Salinity and Temperature Patterns in the Arctic Ocean"
Handouts of maps of surface seawater salinity and temperature data for the Arctic Ocean
Colored Pencils

Technical Requirements:

Computer with access to Internet and LCD projector to show images of global salinity and temperature maps
Alternative – overhead projector with transparencies of global salinity and temperature maps or class set of laminated color copies of maps for reference.

Teacher Preparation

Read about ocean water characteristics in an earth science or oceanography textbook or visit one or more of the sites listed as references in the background information section of this lesson plan.

Prepare your own color maps of Arctic Salinity and Temperature Patterns. Students who get "stuck" during the lesson may find it helpful to see a completed map – just don't let them copy your map!

Download images of global seawater salinity and temperature maps to project for class. If no projector is available, make a class set of laminated color copies for reference.

Prepare copies of lab handout including maps. Have extra copies of maps.

Keywords: salinity, temperature, sea ice

Pre-Assessment Strategy

Students should read about the characteristics of ocean water prior to this lesson. Begin the class with a discussion of what makes seawater different from fresh water. Show students an image of a global seawater salinity map. Students should study the map in small groups and brainstorm a list of factors that cause variations above and below an average salinity of 35 parts per thousand. Have students identify areas with higher and lower than average salinity and consider which factors are important in those regions. Point out that global salinity maps generally do not include much data for the Arctic Ocean and ask students why they think that is true.

Remind students of the causes of Earth's seasons. Ask students what causes global and seasonal variations in temperature. It might be necessary to prompt them about the connection between latitude and the angle and amount of incoming solar radiation received by different parts of Earth's surface. Show students a series of images of global ocean temperatures from different times of the year – at a minimum, use one map from the summer and one from the winter. Ocean water heats and cools more slowly than land, and surface currents help circulate heat from tropical latitudes to higher latitudes, but the patterns of ocean temperature are still primarily influenced by latitude and the angle of incoming solar rays.

Lesson Procedure

1. Give each student a copy of the lesson handout entitled "Salinity and Temperature Patterns in the Arctic Ocean" and the two Arctic maps with salinity and temperature data. Read through the introduction as a class.
2. Project the maps on an overhead. Have students preview the maps and share their first impressions with the class.
3. If necessary, demonstrate the color-coding step on one of the maps.
4. Allow students to work individually or in small groups, each preparing their own maps. Encourage them to look at each other's maps but emphasize that it is not necessary for their maps to be identical. Students are asked to make inferences about values between the marked points. Some may be uncomfortable with this, and it may be necessary to demonstrate how to transition and blend colors between points. Circulate around the room to troubleshoot student concerns.
5. Students should finish the maps at their own pace and then use the maps to answer the questions. Encourage small group discussion before students record their answers. Emphasize to students the importance of interpreting the reasons for the trends they see on the maps.
6. Students should hand in completed maps and questions.
7. Follow up lesson with a discussion of student observations. What was unusual about the patterns in the Arctic? How easy or difficult was it to estimate the location of sea ice based on the water chemistry data? Are the patterns in the Arctic influenced by the same factors as in global oceans? Why or why not?
8. Optional -- follow this lesson with a discussion of the potential impact of global climate change on the Arctic Ocean. Let students discuss what they have heard in the news and

encourage them to make inferences based on their knowledge of Earth systems. What obvious changes would they expect? What subtle changes might occur?

Assessment and Evaluation

Student learning will be assessed based on the quality of their maps and their answers to the questions in the lab. Maps should include logical, consistent inferences of data between mapped points, especially in regions where there are sudden changes in values such as near the Bering Strait and the Mackenzie River. Temperature map should include estimated location of sea ice that roughly corresponds to the region where surface seawater temperatures are below 0°C. Student responses to questions should be graded based on whether or not they are able to identify 2 or 3 factors that influence local variations in salinity and temperature within the Arctic and in comparison with global patterns. Students should recognize that most variations are related to different water sources entering the Arctic: (a) lower salinity and warmer water near the Mackenzie River and near the Alaska coastline where freshwater enters the ocean; (b) lower salinity and colder water ice edges; and (c) higher salinity and warmer water where Pacific water flows into the Arctic at the Bering Strait. Students may also observe that salinity and temperature values are relatively consistent in surface water beneath the sea ice.

Standards

- **National Science Education Standards Addressed**

  U: Unifying Concepts and Processes
  - U.1 Systems, Order & Organization
  - U.2 Evidence, Models & Explanation
  - U.3 Change, Constancy & Measurement

  A: Science as Inquiry
  - A.1 Abilities to do scientific inquiry
  - A.2 Understandings about scientific inquiry

  D: Earth and Space Science
  - D.1 Energy in the earth system
  - D.2 Geochemical cycles

  F: Science in Personal and Social Perspectives
  - F.4 Environmental quality

  G: History and Nature of Science
  - G.1 Science as a human endeavor
  - G.2 Nature of scientific knowledge

- **Ocean Literacy Principles Addressed**

  Principle 1. The Earth has one big ocean with many features.
  Fundamental Concepts a, e, f, and g

  Principle 2. The ocean and life in the ocean shape the features of the Earth.
  Fundamental Concepts a and c

  Principle 3. The ocean is a major influence on weather and climate.
  Fundamental Concepts a, b, f, and g

  Principle 7. The ocean is largely unexplored.
  Fundamental Concepts a, b, d, and f

- **Massachusetts Science Standards Addressed**

  Earth and Space Science, High School Content Standards
  1. Matter and Energy in the Earth System – 1.3, 1.4, 1.5, 1.7 & 1.8

3. Energy Processes and Cycles – 3.5
Scientific Inquiry Skills Standards
S1S1. Make observations, raise questions, and formulate hypotheses.
S1S3. Analyze and interpret results of scientific investigations.
S1S4. Communicate and apply the results of scientific investigations.

Additional Resources
Videos: Discovery Channel School – *Understanding: Oceans*
BBC – *The Blue Planet: Ocean World* and *Frozen Seas*

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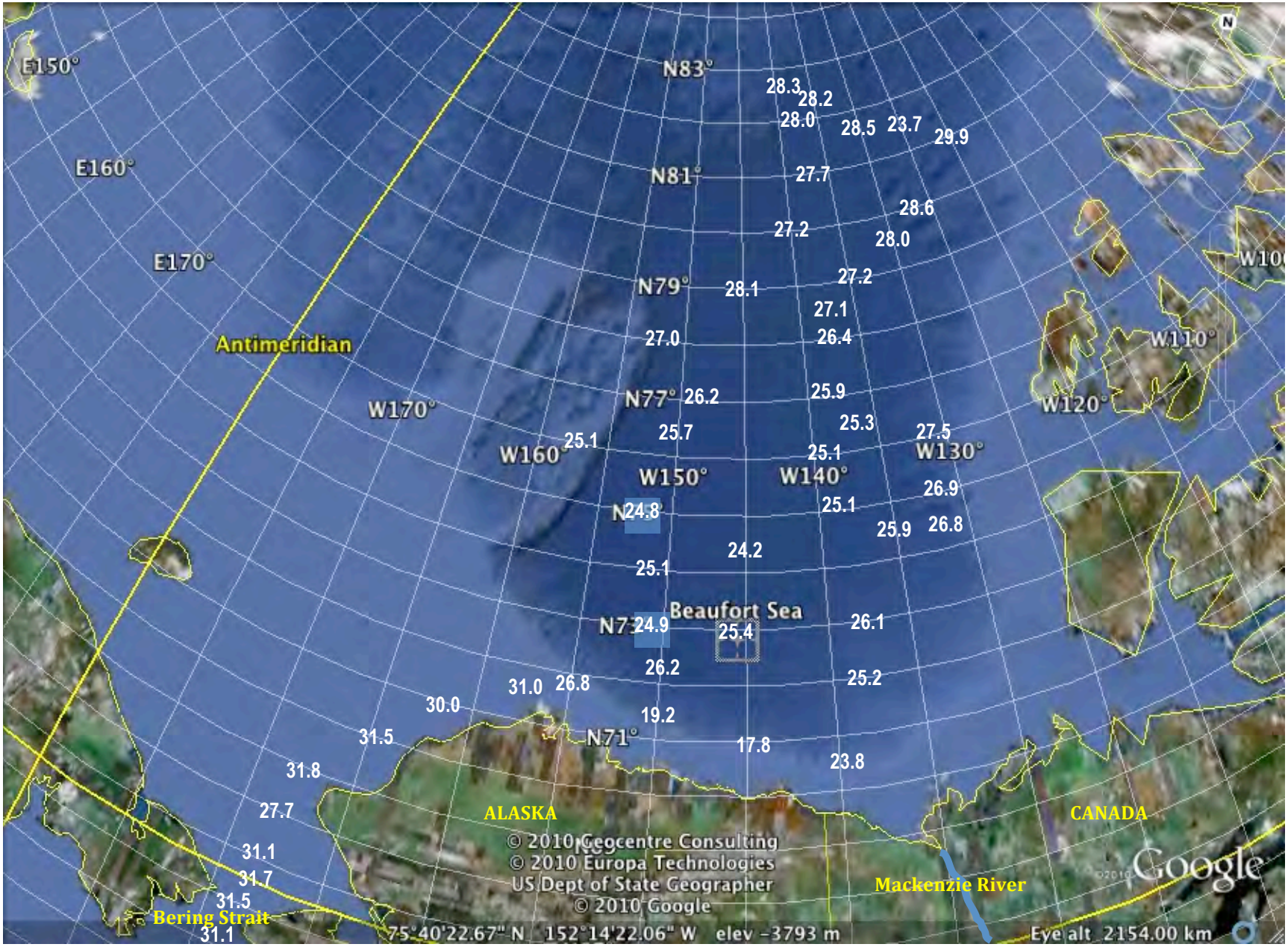
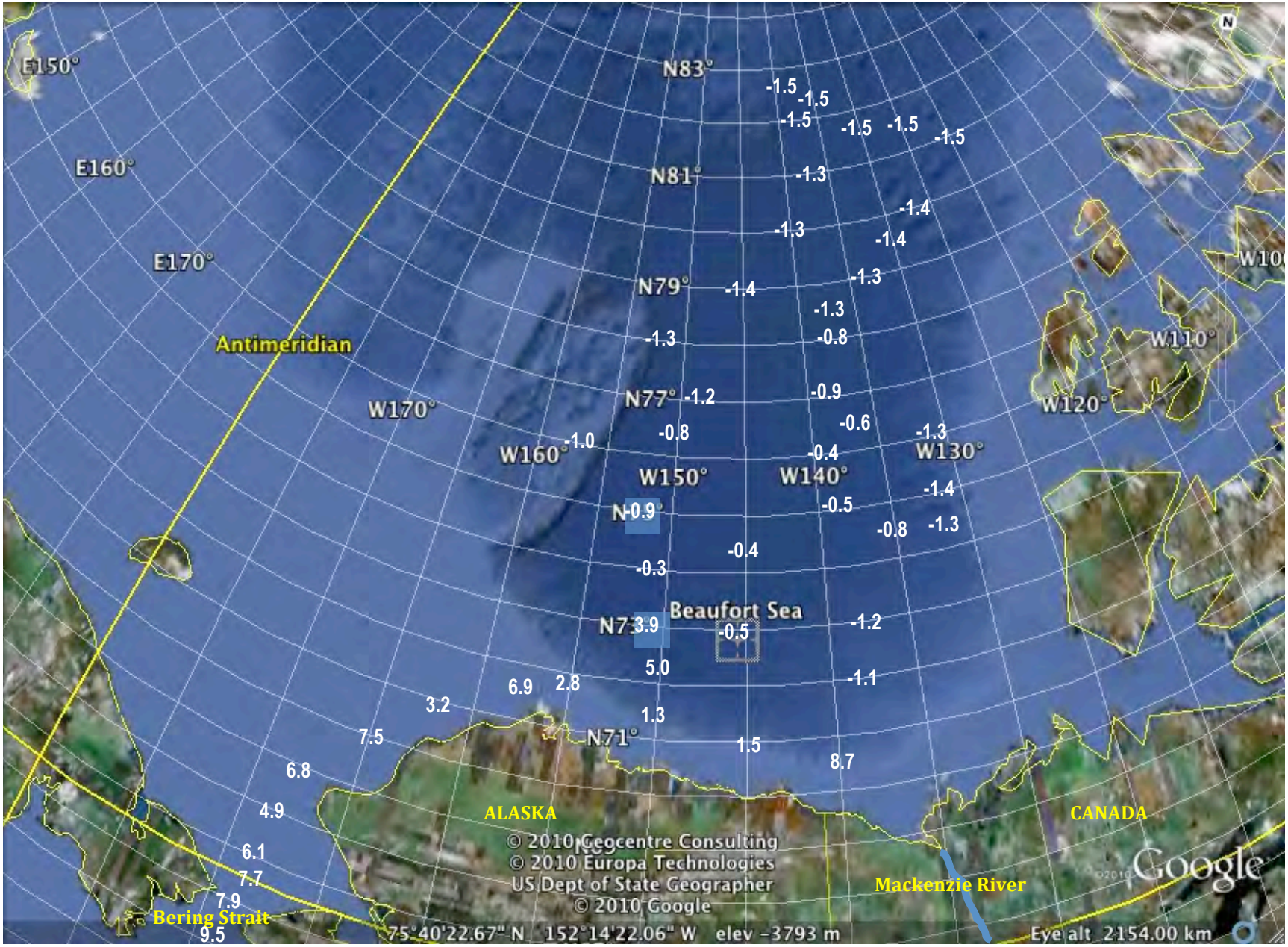
Map One: Arctic Ocean Surface Seawater Salinity August 2010



Data collected on USCGC *Healy* between 5 August and 5 September 2010. Data are in practical salinity units (PSU).

Map Two: Arctic Ocean Surface Seawater Temperature August 2010



Data collected on USCGC *Healy* between 5 August and 5 September 2010. Data are in °C.

Name _____ Date _____

Salinity and Temperature Patterns in the Arctic Ocean

Most maps that illustrate the characteristics and circulation of the world's oceans do not provide much data for the Arctic Ocean. Sea ice covers the Arctic for more than half of the year, and the waters are inaccessible to most research vessels. Changes in global temperatures have resulted in longer melting seasons in the Arctic in recent years. Scientists are taking advantage of increased access to do more oceanographic research in Arctic waters. One research cruise to the Arctic is staffed by dozens of different scientists involved in a variety of activities including bathymetric mapping, water quality sampling and analysis, and installation of buoys that collect data about weather, ocean circulation, and sea ice movement.

The attached maps show data collected by the U.S. Coast Guard Cutter *Healy* during an expedition conducted in August and September 2010. The ship is equipped with a flow-through water sampling system that collects surface seawater samples at one-minute intervals. Salinity and temperature are two parameters for which samples are continuously tested. The maps show a region of the Arctic Ocean north of Alaska called the Beaufort Sea and Canada Basin. The Bering Strait is on southwestern side of the map; the Mackenzie River flows into the ocean near the southeastern side of the map. The islands in the east are part of Canada. The grid lines on the map are latitude and longitude.

Part One – Arctic Ocean Surface Seawater Salinity

Map One shows surface seawater salinity values measured in practical salinity units (PSU). Choose a different color for each of the salinity ranges and make a key on the table below. Color-code the points on the map. Then fill in the areas between the points by making inferences about salinity values – if adjacent points are in the same range, you may infer that the area between them is also in the same range and you can blend the colors between those points. If there is a range missing between two points, you may infer that the salinity transitions through the region between the points. Do not worry if your map looks a little different from the maps of your classmates; make your best, most logical inferences. When your map is complete, it will show the surface seawater salinity pattern in the region traversed by the *Healy*.

Color	Salinity Range (PSU)
	16.1-18.0
	18.1-20.0
	20.1-22.0
	22.1-24.0
	24.1-26.0
	26.1-28.0
	28.1-30.0
	30.1-32.0

Use the map to answer the following questions.

1. Describe the pattern of surface salinity values shown on the map. What is the overall range of values? How consistent are the values overall? Where are the highest and lowest values? Are the variations gradual or sudden and dramatic?

2. How do average surface salinity values in the Arctic Ocean differ from average salinities in the rest of the world's oceans, as shown on the map in your notes? Suggest possible reasons for the differences.

3. In which region(s) is/are the lowest salinities shown on the map? _____

   Suggest possible cause(s) for the lower than average values. Review your notes about the factors that can cause a decrease in salinity and determine whether any of those factors may have influenced the Arctic during the time period shown on the map.

4. In which region(s) is/are the highest salinities shown on the map? _____

   Suggest possible cause(s) for the higher than average values. Consider the possible factors that can increase salinity and determine whether any of those factors may have influenced the Arctic during the time period shown on the map.

Part Two – Arctic Ocean Surface Seawater Temperature

Map Two shows sea surface temperatures, in degrees Celsius, for the same region as Map One. Select a color to represent each temperature range and make a key on table on the next page. Color-code the points on the map. Fill in areas between the points by making inferences about the temperatures based on the trends observed for the measured points. Keep in mind that the data were measured over a one-month period, not on the same day. When your map is complete, it will show the surface seawater temperature pattern in the region traversed by the *Healy*.

Color	Temperature Range (°C)
	< -1.0
	-1.0 to 1.0
	1.0 to 3.0
	3.0 to 5.0
	5.0 to 7.0
	> 7.0

Use the map to answer the following questions.

5. Describe the temperature pattern shown on the map. What is the overall range of values? How consistent are the values overall? Where are the highest and lowest temperatures? Are the variations gradual or sudden and dramatic?

6. What is the major factor that controls global patterns of sea surface temperature? (Hint: it's the same factor that controls temperature anywhere on Earth!) _____

7. Notice that the lowest temperatures are below 0°C. Dissolved salts in seawater depress the freezing point, and salt water stays liquid to lower temperatures than fresh water. The *Healy* is an icebreaker vessel – the ship can plow through sea ice, allowing access in places that are inaccessible for other research vessels. As a result, many of the data points on the map are for water samples collected from <u>just below</u> the sea ice rather than in open water.

   Based on the temperature patterns, infer where you think the *Healy* encountered sea ice in August 2010. Use a different color than any used on the temperature map to outline the region where you infer that sea ice covered the water. Draw diagonal lines across the region that you think was covered by ice. Explain your reasoning for selecting the region you did.

8. Notice the locations of the warmest temperatures measured in the region. What are some possible sources for the warmer water in these areas? Use the geographic information shown on the map to help you answer this question. _____

9. What happens to the salinity of surface seawater when sea ice melts? _____
   What happens to surface salinity when sea ice forms? _____

10. Compare the two maps. Is there a relationship between the area that you inferred was covered with sea ice and the salinity pattern on Map One? Describe and try to explain any similarities and differences between the two maps.

11. Temperature and salinity are two important physical characteristics of seawater that drive global ocean water circulation. Polar regions are a source region of water for deep ocean currents. How is density affected as water temperature decreases and salinity increases?

    Examine a map of world oceans. Where are the outlets of deep ocean water from the Arctic Ocean into other ocean basins?

12. Predict how the temperature and salinity patterns in the Arctic Ocean will change with seasonal changes throughout the year.